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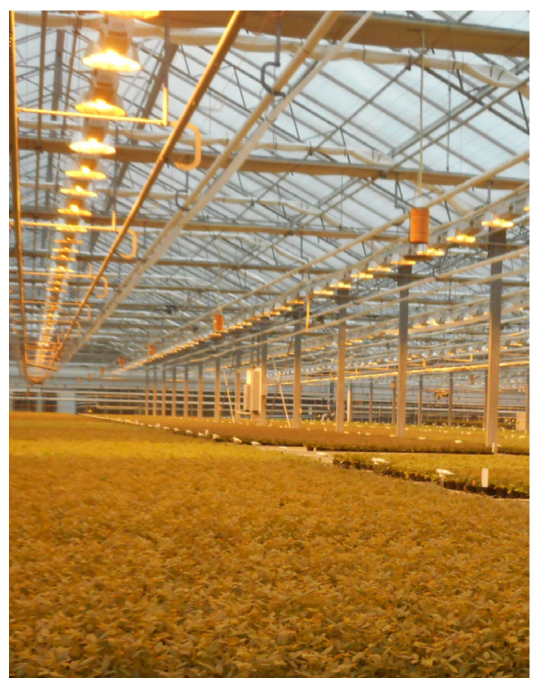
How Many Light Fixtures Do I Need?

Thinking of adding or upgrading supplemental lights in your greenhouse? This alert will walk you through estimating how many light fixtures you need and their electricity cost.

Thinking of adding supplemental lights to your greenhouse? It is relatively easy to calculate a rough estimate of how many fixtures you need if you know your target light intensity (in μmol/m^2/s) and the light output (μmol/s) from a given fixture. You can also estimate your annual electricity bill from lighting if you know the power consumption of a fixture (in Watts) and an estimate of how many hours it will be on a year. Let's put on our thinking caps and dive into some calculations, but first let's start with a reminder of light units and target light levels for some crops.



PAR, PPFD, and DLI

For plant photosynthesis, we are interested in all photons of light between 400 and 700 nanometers (nm), this is referred to as Photosynthetically Active Radiation (PAR). The unit we use for measuring instantaneous light upon a given surface per unit time is micromoles per square meter per second (or μmol/m^2/s) of PAR. This is referred to as the Photosynthetic Photon Flux Density (PPFD). This is the amount of energy (photons or particles of light) hitting a square meter every second. The term mole is a really large number, 6.02×10^{23}, a micromole (μmol) is one-millionth of a mole.

The Daily light integral (DLI) is the accumulation of all the PAR received during a day. The unit for cumulative light or daily light integral moles per square meter per day (or $mol/m^2/day$).

If you measure the instantaneous light (PPFD) provided by a given light source ($\mu mol/m^2/s$) and know how many hours a day it is turned on, you can calculate the DLI ($mol/m^2/day$) it provides. You need to remember that an hour as 3,600 seconds, and that 1 mol = 1,000,000 μmol.

Example:

A light fixture provides 100 $\mu mol/m^2/s$ PPFD how many mol/m2 does it provide when on for 1 hour?

(100 $\mu mol/m^2/s$ x 1 hour x 3,600 seconds/hour) / 1,000,000 μmol/mol = 0.36 $mol/m^2/hour$

If the same fixture is on hour 16 hours a day, how many $mol/m^2/day$ is provided by the light?

0.36 $mol/m^2/hour$ x 16 hours/day = 5.76 $mol/m^2/day$ DLI.

Two excellent resources are: Measuring Daily Light Integral in a Greenhouse which further describes lighting units and conversions and Supplemental Light Calculator (DLICALC) a simple online tool that can calculate the DLI provided by a lighting fixture or help you calculate how many hours a day a light fixture needs to be on to achieve a target DLI.

Target DLI

Within bounds an increase in light quantity leads to an increase in photosynthesis and crop biomass. For vegetable crops this often means for every 1% increase in light you can expect a 1% increase in yield (again only up to some upper bound). However, the optimum daily light integral (DLI) varies according to each crop. Optimal DLI also depends on other growing conditions (such as temperature and carbon dioxide concentration). Some rough guidelines are provided in Table 1. Floriculture crops are quite diverse with greatly varying ranges, check out: Measuring Daily Light Integral in a Greenhouse for more details.

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Now let's move on to calculating how many light fixtures to install. You will need to know your target PPFD and the total light output from a given fixture.

Target PPFD

When making decisions about installing supplemental lights, you will need to determine the target PPFD (µmol/m^2/s). This will be based on a number of factors including the crop, how important it is for you to achieve stable crop growth during the dark months, how much natural sunlight you get during the darkest months, and how many hours a day your fixtures can be on (which depends on crop photoperiod requirements). For example, let's assume we are growing lettuce in a northerly location – we know that during some of our worst winter days in January we get only 3 mol/m^2/day. However, we want to target 15 mol/m^2/day so that we can consistently deliver crop to market. Therefore we need install enough lighting capacity to achieve 12 mol/m^2/day. Let's further assume we can operate the lights for 18 hours a day (in fact for lettuce you can use up to 24 hours light a day without harming the plant, however for tomatoes you need a 4-6 hours dark period). So in our example to provide 12 mol/m^2/day across 18 hours, means we need to supply 12/18 = 0.667 mol/m^2/hour. We can then calculate our target PPFD:

0.667 mol/m^2/hour x 1,000,000 µmol/mol x 1/3,600 seconds/hour = 185 µmol/m^2/s

So in this example we would install enough light fixtures to achieve an average PPFD of 185 µmol/m^2/s. An important note, is that light quantity from bulbs/fixture declines over time so it can be useful to target a higher PPFD than initially needed to that you can still obtain the target PPFD even as

Table 1. Suggested DLI targets for greenhouse crops.

Crop	Minimum DLI (mol/m2/day)	Optimum DLI (mol/m2/day)
Beddings plants	8	10-12
Head lettuce	12	17*
Cucumbers	15	>30
Peppers	20	>30
Tomatoes	20	>30
Strawberries	17	>20

*At high light (i.e. fast crop growth) lettuce is very sensitive to tip burn (a physiological disorder due to calcium deficiency). Vertical air flow fans should be used when to reduce incidence of tipburn, otherwise a lower DLI target must be used.

fixtures begin to age.

Output from a Light Fixture

The total amount of light provided by a fixture is given in units of µmol/s. This is measured in a specialized piece of equipment called an integrating light sphere; all the photons emitted from a fixture are accounted for, and a sensor measures average PPFD in the sphere. Reputable manufacturers of horticultural lighting fixtures will be able to provide this number to you for their fixtures.

Fixtures Required to Light an Area

Warning! To calculate the area a fixture can light we need to make a couple big assumptions 1) we assume that the fixture has uniform light coverage across the area it lights and 2) we assume we can adjust the height of a fixture so as to achieve a given light target and light coverage. These assumptions are definitely not true in the real world – however, in the real world we typically adjust spacing between lights achieve decently uniform light distribution (taking advantage of overlapping light between fixtures). Therefore, the calculations we do here should be thought of as rough estimates of the number of fixtures needed to light an area. In practice, growers should consulting lighting manufacturers who can provide provided detailed maps of how the fixtures should be set up and of light uniformity.

Despite these major limitations we'll proceed with our estimates. If we have a target PPFD in mind that we would like a fixture to provide, we can calculate how many square meters one fixture can light. For example:

A given light fixture, a 600 W high pressure sodium (HPS) light has light output of 1,092 µmol/s

If our target PPFD is 200 µmol/m^2/s how many square meters can this fixture theoretically light?

1,092 µmol/s / 200 µmol/m^2/s = 5.46 square meters

How many square feet is this? 5.46 m^2 x 10.8 ft^2/m^2 = 58.97 ft^2

Power consumption of a light fixture

The power consumption of a light fixture is reported in Watts (W) which is equal to a Joule (J) per second. A kWh (kiloWatt hour) represents the use of 1,000 W for 1 hour (3,600 seconds). Note that for HPS fixtures, they consume some additional power beyond just the bulb, for the ballast. So in our example of a 600 W HPS fixture, let's say it was measured by an energy meter to draw 700 W of electricity. (Again, the manufacturer can also supply this information).

If this fixture is plugged in for 1 hour, how many kWh electricity will it use?

700 W = 0.7 kW x 1 hour = 0.7 kWh

If this fixture is on for 16 hours a day every day of the year, how many kWh electricity will it use?

0.7 kWh x 16 hours/day x 365 days/year = 4,088 kWh / year

Electricity prices vary greatly depending on whether you are a commercial or residential user and your energy supplier. An average residential price for electricity is 10.5 cents per kWh (includes supply and delivery).

How much will it cost to have this fixture turned on for 16 hours/day for 1 year?

4,088 kWh / year x $0.105 / kWh = $429 / year

Estimating fixtures required to light a given area

Let's assume we need to light 277 m^2 (this is a 3,000 square foot greenhouse – a common single span greenhouse size is 30' x 100'). (Remember, 1 m^2 is 10.8 ft^2.)

We already calculated the fixture above can cover 5.46 m^2 at a target PPFD of 200 µmol/m2/s

So we will need about 277 m^2 / 5.46 fixtures/m^2 = 50.73 fixtures, or round up to 51 fixtures

Let's assume the fixtures cost $400 each – how much will it cost to purchase fixtures for the greenhouse?

51 fixtures x $400 cost per fixture = $20,400

Let's assume the fixtures are on for an average of 3,000 hours per year and electricity costs 6.5 cents per kWh (a commercial rate). How much will cost to light the greenhouse for 1 year?

Remember, the fixture power consumption is 700 W (so for each hour lit requires 700 W = 0.7 kW x 1 hour = 0.7 kWh). So 51 fixtures lit for 3,000 hours:

51 fixtures x 0.7 kWh/hour x 3,000 hours/year x 0.065 $/kWh = $6,961.50 / year

Since we are lighting a 3,000 square foot area, this works out to a square foot electricity cost of $6,962/3,000 sf = $2.32 / sf/year.

Again, remember the caveats, that these are only estimates and do not tell you anything about light fixture mounting height and spacing. These estimates are particularly helpful when you want to compare the pricing and energy cost of some different types of light fixtures. You can do these calculations once you have the light output (µmol/s) and power consumption (Watts) from each fixture.